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REPLY TO HORSWILL AND MANICA: FTLE is one of a suite of oceanographic variables useful for predicting bycatch risk in marine fisheries

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Horswill and Manica (1) provide a useful extension to Scales et al. (2), quantifying the relative risk of bycatch for each swordfish caught at several values of backward-in-time Finite-Time Lyapunov Exponent ($FTLE_b$), a parameter derived from ocean surface velocity that identifies aggregative features known as Lagrangian coherent structures (LCS). We concur that the catch ratio of target to nontarget species with respect to the location of these structures is a useful measure for guiding spatial bycatch mitigation strategies in marine fisheries, but we want to highlight some aspects of Horswill and Manica's response that require clarification.

First, Horswill and Manica (1) combine all nontarget species together in one group for analysis, whereas Scales et al. (2) present separate results for multiple guilds of nontarget species. Each of these species has a particular ecological niche, influencing foraging behavior and use of the water column, which, in turn, influence bycatch risk. These species-level differences are key to the recommendations in Scales et al. (2), since the fishery is primarily concerned with avoiding bycatch of protected marine megafauna.

Second, Horswill and Manica (1) show that intermediate values of $FTLE_b$ are associated with the lowest bycatch risk for every swordfish caught and assert that relocating fisheries effort based on absolute values of $FTLE_b$ would have unintended consequences. Scales et al. (2) do not recommend relocation based on $FTLE_b$ magnitude alone, and even if this were done, we would not recommend intensifying fisheries effort at the lowest $FTLE_b$ values, owing to high relative bycatch rates. Indeed, the lowest values of $FTLE_b$ occur sparsely in this spatial domain, organized as linear ridges fringed with ribbons of intermediate values (see ref. 2). Hence, we agree with Horswill and Manica that using intermediate values of $FTLE_b$ to identify regions of highest catch-to-bycatch ratio is the logical recommendation.

Moreover, we strongly agree that multiple environmental parameters are required to predict spatiotemporal variability in catch and bycatch rates, particularly in highly productive and dynamic systems such as the California Current. Hence, we have developed a multiparameter predictive tool, EcoCast, which integrates satellite remote sensing, animal tracking, and fisheries data to nowcast relative catch-to-bycatch ratios for this fishery (3–5).

$FTLE_b$ would be a valuable addition to the physical data fields integrated into EcoCast, but this is not currently possible. The $FTLE_b$ parameter used in Scales et al. (2) is derived from a data-assimilative California Current System configuration of the Regional Ocean Modeling System (6). The integration of ocean model output into marine ecological nowcasting and forecasting is in process (7) and will provide an opportunity to optimize predictive performance of tools such as EcoCast, allowing for the inclusion of model-derived physical data such as $FTLE_b$ and, importantly, subsurface fields (4, 8). Moving forward, the increasing availability of ocean model products will be a boon in dynamic ocean management (9), enabling recommendations such as those in Scales et al. (2) to be put into effect to solve real-world fisheries problems (10).

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